IMPLICATIONS OF THE SHALE GAS BOOM FOR THE GCC PETROCHEMICAL PRODUCERS

By: Hoda Mansour¹

Summary:

The paper tries to study the potential impact of US shale gas revolution on the GCC petrochemical production. The paper was divided into four main sections; the first section focused on the history of shale gas production and reasons behind its boom. The study found that shale gas boom came after development of drilling methods that combined horizontal drilling with hydraulic fracturing, side by side with the improvement to hydraulic fracturing or “fracking”. These developments enabled companies to drill into 10,000 feet deep and then deep horizontally to drill shale rocks. The second section presented the development of shale gas production and its impact on US energy market. The study found that shale gas production in large amounts led to a decrease in US natural gas prices. The downturn of natural gas prices gave life back for the petrochemical industry in the United States.

The third section of the study gave special attention on the status of petrochemical industry in the GCC countries. The study found that petrochemical industry have had significant developments through the first decade in current century. The annual growth rate of petrochemical feedstocks during the 4 years period reached 15% as total production increased from 26.4 million tons in 2007 to 45.4 million tons in 2011. Petrochemical industries represents a great importance for the GCC countries for many reasons; most important ones is that it helps countries to maximize their profits from oil and natural gas production, as it also helps to reduce unemployment by creating lots of jobs for natives.

The fourth section highlighted the researcher's methodology to study Impact of shale gas revolution on GCC petrochemical production. The overall results, using linear regression model, indicated that there is a positive linear relation between the GCC Petrochemicals production in million tons and the withdrawals from shale Gas wells in billion cubic feet. However, that doesn't necessarily means that they affect each other, as the model clarifies that the production of one billion cubic feet of shale gas increases the production of petrochemicals by four thousand tons only. That conclusion proves that the study hypothesis is not right, as the increase in U.S.

¹ Assist prof. of economics, College of Business Administration, University of Business and Technology, Jeddah, KSA.
shale gas production have a positive weak relation on the production of GCC petrochemicals. Analysts believe it is too early to speak of a direct effect from U.S. shale gas on GCC petrochemical production. The study, instead, found in future shortage of natural gas liquids production more threatening trouble for GCC petrochemical production, rather than US shale gas production.
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Abstract:
During the last decade, the U.S. energy industry witnessed unprecedented developments in oil and gas production, due to the boom in shale gas production. In 2012, the U.S. Energy Information Administration (EIA) estimated in its Annual Energy Outlook, a growth rate for the overall U.S. natural gas production of about 28% during the period (2010-2035), which shall reduce the country’s dependence on imported petroleum. In addition, the EIA expects some level of North American gas exports in the next four to eight years. Therefore, shale gas opens new horizons for U.S. petrochemical players, which can represent a potential threaten the GCC petrochemical producers.

This paper aims to shed light on the possible effects of the American shale gas revolution on the Gulf Cooperation Council “GCC” petrochemical players to see if there is any response that needs to be formulated to face any potential threat. The paper analyzed the relationship between the U.S shale gas production and the gulf petrochemical production through a regression model to taste the hypothesis saying that there is inverse relationship between U.S shale gas production and the gulf oil and petrochemicals production. The study used the model also to measure the relation between, GCC's LNGs production, and GCC’s petrochemical production.

The overall results, using the model, indicated that there is a positive linear relation between the GCC Petrochemicals production in million tons and the withdrawals from shale Gas wells in billion cubic feet. The results also indicated that relationship between the U.S. gas production and natural gas prices is not a statistically significant. Although it is too early to determine the specific influence of these developments on the GCC we can say that the current situation may presents both threats to the profitability of GCC petrochemical players on the long run as well as new growth opportunities to consider.

Keywords: Shale gas, US new energy, GCC political economy, petrochemical producers
2. Introduction

Shale gas production is not new but nobody believed in it as a source of potential reserves before. Historically, there has been no real desire to develop shale gas reserves, as it was simply perceived as a source and seal rocks. In addition, after discovering that hydrocarbon remains bound in the shale rocks and they work as reserves, yet developing gas from shale rocks was not economically attractive. Today after its boom, experts look at shale gas as a “game changer”. (Marcus, 2012) as it will be able to push the natural gas prices down, specifically after the development of drilling technology which increased the production from 1% to 20% between 2000 and 2010.

In fact, the boom was backed by many reasons; the first started during the 80s and 90s when the US Department of Energy (DOE) funded some projects aiming at developing the usage of well drilling and hydraulic fracturing. Efforts were crowned success as it led to the development of drilling methods that combined horizontal drilling with hydraulic fracturing in-order to gather natural gas from organic shale. This new drilling method took place in parallel with developments in 3D fracturing simulators and computing power where the extraction of huge amounts of shale gas becomes an easy task. (James G. Speight: 2013, 25-28) The new method allowed producers to expand the amount of shale exposed for extraction.

The second factor that helped in increasing shale gas production is the improvement to hydraulic fracturing or “fracking”. Fracking is considered as the process that maximizes the output of natural gas and oil wells to make them productive through pumping a mixture of water, sand and small amount of chemicals into gas formation that is located underground in order to help in increasing pressure. The increased pressure fractures rock layers to release oil and gas reserves, where the sand holds the fractures open to continue allowing the flow of oil and gas into the well. When the gas is being flowed out of the well it brings with it the mixed water that was pumped then the water is separated from the gas at the surface and then it is sent to deep injection wells for disposal as figure 1 illustrates.
Figure 1: Geology of Shale Gas and Conventional Natural Gas

Shale gas became an important and profitable source of energy owing to the advanced drilling and production methods. Moreover, shale gas mostly occurs in continuous formations unlike conventional natural gas and oil, which makes the shale gas development and production closely related to manufacturing operations than the process take place in producing conventional gas and oil.

Therefore, shale gas share out of all natural gas production increased from 1.6 % in 2000 to 4.1 % by 2005 and to an astonishing rate of 23.1 % by 2010. (Zhongmin Wang and Alan Krupnick, 2013) Figure 2 and 3 illustrate how the shale gas production increased 12-fold
through the last decade and now comprises around 25% of the aggregate U.S. production, which increased the U.S. natural gas supply.

Figure 2: US dry gas by source – Trillion Cubic Feet per Year

The US Department of Energy indicated in its Annual Energy Outlook of 2012 that total unproved shale gas resources have more than quadrupled since 2006 to reach 482 trillion cubic feet at the end of 2011, representing 22% of total U.S. unproved natural gas resources. Again, the DOE in its Annual Energy Outlook of 2013, mentioned that Shale gas production, which cumulatively will grow by 113% from 2011 to 2040, is the greatest contributor to natural gas production. So shale gas share of total production is estimated to increase from 34% in 2011 to 50% in 2040. No doubts that such an increase in shale gas production lowered the prices of the natural gas, and accordingly foster the growth for industrial production and energy consumption in the US. (EIA, 2013).
Due to increased production and decreasing cost, shale gas introduced itself as solution for the efforts to secure lower risk/cost gas supplies, which decreased the need to import gas. As it is illustrated in figure 4, the high rate of consumption of natural gas in US has increased the natural gas imports to reach 2 trillion cubic feet in 2011. However, the boom in shale gas production reduced natural gas prices in US and made it attractive market, increasing the estimated US exports of natural gas to 12% in 2040, despite the high rates of local consumption. (EIA, 2013)

Moreover, according to the IEA in its recent report, the U.S. will surpass Russia and Saudi Arabia as the world’s top oil producer by 2015, and be close to energy self-sufficiency in the next two decades, amid booming output from shale formations. (Grant smith, 2013)
3. **Shale Gas and U.S. Petrochemical Industry**

The industry of chemicals witnessed enormous discoveries since the second half of last century; these discoveries included PVC plastic, nylon, synthetic rubber and polystyrene. A large percentage of gas consumption (around 46%) is directed to chemicals and refining industry. Ethylene is considered as a key component in manufacturing plastics and other chemical products, beside some other intermediates such as propylene, butadiene and benzene. The production of ethylene and other intermediates is based on the two kinds of feedstocks, the first one is naphtha, which is being produced from oil. The second, is Natural Gas Liquids (LNG) like ethane, propane and butane. The shale gas is mainly composed of Natural Gas ‘Methane’, and LNG ‘Ethane and Propane’, which means that shale gas revolution had its own impact on chemical industry through driving down prices of essential feedstocks for petrochemical industry, especially ethane.
USA petrochemical industry traditionally depended on naphtha, produced from oil, to produce ethylene, propylene, butadiene and benzene after a steam cracking process, and that was somewhat very expensive. The US chemicals industry was expected to face a real challenge on the long-term due to high cost, where Companies such as Dow Chemical were expecting to shift their future investments toward the Middle East but after the boom, the situation changed upside down. The natural gas prices were the first to be affected by the revolution as their prices went down 68%. Figure 5 illustrates how the natural gas prices in the US started to take a down trend in comparison to other countries.

**Figure 5: Trends in Natural Gas Prices around the World**

![Trends in Natural Gas Prices around the World](image)

Source: American Chemistry Council (ACC), 2013

Also figure 5 shows that the natural gas prices in the United States were regarded as one of the lowest in the world by 2012. However, the natural gas prices in Saudi Arabia are still lower at $0.75 per million BTUs in stable market while the prices in the US were at $3 per million BTUs, but still the fact is that the US is back from a decade of really high prices. (EIA, 2013)

The US petrochemical industry did not depend so much on LNGs as a feedstock to produce ethylene and propylene due to the high prices of natural gas, but that changed directly
after the shale gas revolution increased the available amounts of LNGs as ethane and propane as shown in figure 6, which pushed the shale gas impact to override the high prices of natural gas and its effects on the petrochemical industry in the US.

**Figure 6: U.S. production of natural gas liquids by type, 2005-2012**

(Million barrels per day)

The increased amount of feedstocks such as ethane and propane pushed the American market to find new ways to efficiently use it. According to figure 7, in 2005, the production of ethylene, which is the most important intermediate for petrochemical industry, mainly depended on LNGs from conventional gas by 65%, naphtha by 32% and LNGs from shale gas by 3%. The increased production of shale gas led to increasing the share of LNGs from shale gas as feedstocks in the production of ethylene to reach 19% in 2010, and expected to reach 28% in 2015.
The global competitive landscape for the petrochemicals industry has been reshaped due to lower prices of natural gas and feedstock owing to shale gas exploration boom. The new natural gas prices in the US pushed the petrochemicals industry total cost to some levels lower than that in Latin America, Europe, and even China. By that, the US market will be able to earn an advantage over many markets around the world in the production of petrochemicals. Accordingly, many international petrochemical companies started to establish some of their projects in the American market to take advantage from the growth of natural gas due to shale gas production. Also, The Energy Information Administration “EIA” estimates that the American market will have 14 new projects to produce ethane and propane with a capacity of 10.1 million metric tons annually.

For example, BASF, the largest chemical company in the world, is sitting its floats across the Atlantic to invest in the American market due to higher prices of natural gas in Europe around the quarter. According to recent estimates, 14 out of 43 crackers in Europe will become uneconomic by 2015 leading to a capacity reduction of 26%. (KPMG, 2013).
Figure 8: Top10 Chemicals Companies by Revenue

Source: Booz & company, 2012

Figure 8 illustrates a comparison between world leading chemical companies in 2002 and 2011 based on revenue. The figure also shows that American chemical companies’ revenues were among the highest in the world, excluding the BASF, Sinopec and SABIC, which are German, Chinese Saudi companies respectively. The revenues of Dow Chemical increased from €29 billion in 2002 to €46 billion and ranked the fourth in the world. ExxonMobil increased by a similar pace from €17 billion in 2002 to €50 billion, and ranked the third in the world. Lyondellbasell (LYB) was the fifth largest chemical company in the world with an increase of €36 billion in its revenues from 2002 to 2011.

The American Chemistry Council (ACC) found that the increase in ethane supply by 25% is impacted by the increase in shale gas production, and the study of ACC found that this increase is going to provide (American Chemistry Council, 2011):

- Create 17,000 new high paying jobs in the US in the chemical industry that is knowledge intensive.
• Create 395,000 new jobs outside the chemical industry (165,000 in related industries, and 230,000 jobs in new capital investments in chemical industries).
• Increase federal, state and local tax revenue by $43.9 billion annually over 10 years.
• Increase in US chemical production by $32.8 billion
• Build new petrochemical and derivatives capacity through $16.2 billion capital investment in the chemical industry.
• Increase US economic output by around $132.4 billion, $83.4 billion out of them are related to increased chemical production, in-addition to the $49 billion that are related to capital investments in the industry.

4. GCC Petrochemical Industry

Petrochemical industry took place in 1976 when Saudi Arabia founded its first company Saudi Basic Industries Corporation (SABIC), 3 years later Qatar started followed the track by establishing Qatar Petrochemical Company (QAPCO) for the production of Ethylene and polyethylene by 1980, also Bahrain initiated her first company Gulf Petrochemical Industries Company (GPIC) to produce methanol. Other Gulf countries joined later, it was in 1997 when Kuwait decided to take part in this growing market by founding EQUATE. Then the UAE joined the industry in 2002 by establishing Borouge, and in 2005 Oman founded Sohar to produce methanol.
By time, petrochemical industries were developed and heavily progressed. As shown in figure 9, the GCC petrochemicals companies are now ranked as the first worldwide in monoethylene glycol production capacity with (29%), while ranked third in methanol capacity (12%), fourth in ethylene capacity (15%), polypropylene (12%), and finally the fifth in both the polyethylene capacity (12%), and the propylene capacity (7%).

On the other side, petrochemical production has shown significant growth during the period from 2007 to 2011 in the whole world in general, and in the GCC countries more specifically. As shown in figure 10, GCC countries scored the highest capacity growth rate for polypropylene (24.8%), propylene (27%), urea (6%), and ethylene (15.7%) during this period. Total GCC petrochemicals capacity grew by 10% in 2011 reaching 121 million tons annually,
with a CAGR of 13.4% during the 4 years period. In 2011, the world petrochemicals capacity utilization rate reached 78%, while it reached 91% in GCC alone. Despite the fact that Asia is considered the largest petrochemical producer in the world, yet its capacity utilization is only 77%. (GPCA, 2012)

Figure 10: Worldwide Capacity growth of top eight petrochemical products 2007-2012

<table>
<thead>
<tr>
<th>Product</th>
<th>GCC</th>
<th>North America</th>
<th>China</th>
<th>Asia (excluding China)</th>
<th>South America</th>
<th>Europe</th>
<th>Africa</th>
<th>the rest of the world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoethylene Glycol</td>
<td>10%</td>
<td>-6%</td>
<td>19%</td>
<td>4%</td>
<td>0%</td>
<td>-5%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>24.80%</td>
<td>-3.40%</td>
<td>17.10%</td>
<td>7.40%</td>
<td>10.30%</td>
<td>-0.30%</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td>Propylene</td>
<td>27%</td>
<td>1.60%</td>
<td>14.20%</td>
<td>7.90%</td>
<td>6%</td>
<td>-0.30%</td>
<td>6.70%</td>
<td>0%</td>
</tr>
<tr>
<td>Methanol</td>
<td>4%</td>
<td>-1%</td>
<td>32%</td>
<td>22%</td>
<td>2%</td>
<td>2%</td>
<td>15%</td>
<td>0%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>11%</td>
<td>-1%</td>
<td>3%</td>
<td>17%</td>
<td>3%</td>
<td>0%</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>12.40%</td>
<td>-0.60%</td>
<td>14.70%</td>
<td>4%</td>
<td>1.60%</td>
<td>0.90%</td>
<td>3.30%</td>
<td>0%</td>
</tr>
<tr>
<td>Urea</td>
<td>6%</td>
<td>0%</td>
<td>2%</td>
<td>-1%</td>
<td>5%</td>
<td>0%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Ethylene</td>
<td>15.70%</td>
<td>-0.50%</td>
<td>14.80%</td>
<td>3.80%</td>
<td>1.50%</td>
<td>0.20%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Source: Mitsubishi Chemical Techo-Research Corporation (MCTR) and GPCA database, 2012

No doubts that the petrochemical industry is of a great importance to the GCC economies for three main reasons; first, this fast growing industry has the key to maintain economic growth in the region. It’s clear that world’s feedstock is brewing, and at the time Ethan is limited to certain countries, extracting more alternatives and transforming it such as methanol to olefins or
gas to liquids gives the GCC region a comparative advantage over other petrochemical players worldwide, as it make it more able to compete in feedstocks market on the long run, which can maintain a sustainable growth rates for GCC countries.

**Figure 11: GCC Basic Petrochemicals Capacity by Product, Million Tons**

Source: GPCA, 2012

As shown in figure 11, the GCC production of ethylene has grown from 12.4 million tons in 2007 to 22.3 million tons in 2011, methanol, propylene and benzene as well have increased from 8.4 mt to 9.9 mt, 3 mt to 7.7 mt, and 1.8 mt to 2.9 mt respectively. The combined annual growth rate during the 4 years period reached 15% as total production increased from 26.4 million tons in 2007 to 45.4 million tons in 2011.

The second reason behind the importance of the industry to the GCC countries is that the industry was established initially to add further value to certain low-value product streams, arising out of crude oil refining and natural gas processing, especially that those downstream products are less exposed to market fluctuations like oil and gas prices. Figure 12 shows that
share of petrochemical industries in the manufacturing sector in the GCC have increased from 13.9% in 2007 to 17% in 2011. The manufacturing sector accounts for 15% in GCC GDP, although, it might seem small percentage, but its importance is backed to job creation on the short run and as an engine of development on the long run after oil and gas depletion.

**Figure 12: Petrochemicals contribution to GDP in GCC countries**

![Graph showing Petrochemicals contribution to GDP in GCC countries](image)


However, Petrochemical share of manufacturing sector contributing to GDP in the GCC differs between GCC countries, at the time it’s share was very high reaching 53.2 % in Oman, 25.8 % in the Qatar, 18.2 % in the UAE, 11 % in Saudi Arabia and 10.6 % in Kuwait, it only accounts for 4.6% in Bahrain. Also The share of petrochemicals non-oil exports was 43%, increasing from 117.2 mt to 128.6 mt, which pushed the GCC revenues to rise from 81.5 billion dollars in 2010 to 105.2 billion dollars in 2011. The high prices of petrochemical products pushed exporting volume to increase by 6% and value by 33%. As the share of petrochemical share of manufacturing sector contribution to GDP vary between different countries within the GCC region, also the share of petrochemicals non-oil exports vary between GCC countries as illustrated in figure 13. In 2011, petrochemical accounted to 72 % from all non-oil exports in
Saudi Arabia, while this percentage was lower in Qatar where it reached 69% followed by Kuwait with 61% and Oman with 39%. On the other side, petrochemicals had a minor share of non-oil exports in both Bahrain and UAE where it represents 8.6% and 9% respectively.

**Figure 13: Petrochemical and chemical percentage of non-oil exports**

![Bar chart showing petrochemical and chemical percentage of non-oil exports for different GCC countries.]

Source: GPCA, 2012

On the revenues side, GCC petrochemicals sales revenue grew by 31.8% in 2011 on year-to-year basis, accounting for 2.1% of a 3.8 trillion dollars worldwide chemical sale, raised from 1.9% in 2010. In Saudi Arabia, the revenues accounted for 61.4 billion dollar in 2011 increased by 27% from 2010. The growth in revenue was huge in Qatar with 58% as sales revenues was 9.8 billion dollar. In 2011, sales revenues in Oman were estimated at 3.9 billion dollar, which represents 4.8% of the regional sales revenues. Producers in Kuwait have increased their sales revenues in 2011 by 21% reaching 3.5 billion dollar in 2011. With 2.6 billion dollar of sales revenue in 2011, the UAE has recorded the highest revenue growth in the GCC by 107%. (GPCA, 2012).
Table 1: GCC Petrochemicals sales revenue by region by million dollar

<table>
<thead>
<tr>
<th>Region</th>
<th>2010</th>
<th>2011</th>
<th>2011 Year-to-Year Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>810</td>
<td>1023</td>
<td>26.2%</td>
</tr>
<tr>
<td>Europe</td>
<td>772</td>
<td>894</td>
<td>15.8%</td>
</tr>
<tr>
<td>Asia (excluding China and GCC)</td>
<td>762</td>
<td>873</td>
<td>14.5%</td>
</tr>
<tr>
<td>NAFTA</td>
<td>592</td>
<td>654</td>
<td>10.4%</td>
</tr>
<tr>
<td>Latin America</td>
<td>186</td>
<td>209</td>
<td>12.5%</td>
</tr>
<tr>
<td>Rest of the World</td>
<td>75</td>
<td>85</td>
<td>14.3%</td>
</tr>
<tr>
<td>GCC</td>
<td>62</td>
<td>82</td>
<td>31.8%</td>
</tr>
<tr>
<td>World</td>
<td>3259</td>
<td>3819</td>
<td>17.2%</td>
</tr>
</tbody>
</table>

Source: GPCA, 2012

Table 2: GCC Petrochemicals sales revenue by country by million dollar

<table>
<thead>
<tr>
<th>Country</th>
<th>2010</th>
<th>2011</th>
<th>Year-to-Year Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>48.416</td>
<td>61.405</td>
<td>27%</td>
</tr>
<tr>
<td>Qatar</td>
<td>6246</td>
<td>9842</td>
<td>58%</td>
</tr>
<tr>
<td>Oman</td>
<td>2883</td>
<td>3912</td>
<td>36%</td>
</tr>
<tr>
<td>Kuwait</td>
<td>2860</td>
<td>3457</td>
<td>21%</td>
</tr>
<tr>
<td>UAE</td>
<td>1272</td>
<td>2631</td>
<td>107%</td>
</tr>
<tr>
<td>Bahrain</td>
<td>312</td>
<td>447</td>
<td>43%</td>
</tr>
<tr>
<td>GCC</td>
<td>61.990</td>
<td>81.695</td>
<td>31.8%</td>
</tr>
</tbody>
</table>

Source: GPCA, 2012

Thirdly, GCC countries are aware of their need to create jobs for their citizens, as the unemployment rates varied depending on economic conditions but generally, the overall rate of joblessness for native and foreign segments has increased since 2000, where petrochemical industries are good in providing jobs for unemployed GCC citizens. Figure 14 illustrates the unemployment rates in GCC countries from 1991 to 2010. As shown in the figure, the unemployment rates are fluctuating over time according to economic conditions, but the rates are getting higher over time from 4.01% in 1999 to 4.72% in 2010. Bahrain and Oman have the highest rates of unemployment, averaging 7.0% and 8.3% respectively, while other countries
have had low levels averaging 5% in Saudi Arabia, 1.26% in Kuwait, 2.4% in Qatar and 2.92% in the UAE.

Figure 14: GCC Unemployment Rates 1991-2010

Source: Gulf Investment Council (GIC), 2011

The unemployment problem is always high among the youth around the world and for sure the GCC countries are no exception. As shown in figure 15, the unemployment rates of youth increased from 17.42% in 2000 to 20.17% in 2010, and indicators show that rates are still going higher. Despite efforts for increasing youth employment, but these efforts are faced with lots of challenges; on top are the expatriates who are enormously dispersed among the GCC countries, whom are having the lion's share in employment at private sector in all of GCC countries. The Gulf Investment Council (GIC) estimates that there are 1.6 million nationals working in private sector in GCC countries, while 900,000 are classified as "unemployed". The concentration of nationals are in the public sector as it reached in 2010 84% and 86% in Kuwait and Qatar respectively.
Manufature sector is not considered to be a labor-intensive sector, as it is depending too much on machines, however downsteam petrochemical manufacturing introduce itself as a labor consumer field as converting chemicals to end-user products requires a pool of skilled labor. Figure 16 illustrate that employment increased in the petrochemical sector from 68.630 employees in 2010 to 79.255 employees in 2011 in the GCC region. Saudi Arabia has the largest share of petrochemical workforce in the gulf in 2010 (70%), and in 2011 (74%). The share of both UAE and Kuwait declined respectively from 12% to 10% and from 8% to 7%. Mainly the petrochemical industry provide job opportunities in different areas such as the R&D, sales and marketing, distribution, customer account management among others.

Recent analysis of the Gulf Petrochemicals and Chemicals Association (GPCA) shows that petrochemicals workforce in GCC countries share from whole workforce reached 6% of the in 2011, where only 44 % of these workforces are nationals in the GCC. The percentage varied between gulf countries as it reached a percentage of 52% with a total number of 58000 people in Saudi Arabia, 83% in Bahrain, 48%, in Oman, 26% in Kuwait, 14% in Qatar and 12% in UAE. As illustrated in figure 17, annual employment growth in petrochemical sector since 2010 is 15%, which is faster than the growth rate of employment in the manufacturing sector that accounted for 7%, making the petrochemicals the fastest growing sector in the gulf economy and
one of the main sectors that provide job opportunities. Some studies found that every one million dollar invested in large ethylene crackers creates one job. However, every million dollar invested in converting ethylene into styrene, and then into rubber, can create up to 20 jobs.

**Figure 16: Employment in petrochemicals sector**

2010 (68,630 employees)  
2011 (79,255 employees)

Source: Gulf Investment Council (GIC), 2011

**Figure 17: Y-to-Y growth of employment in petrochemicals sector, %**

Source: GPCA, 2012
5. **Research Design**

   a. **Data sources**

   The study is based on two variables; the independent variable which is US shale gas production, and the dependent variable which is GCC petrochemical production. Data for both variables in its modern form are only viable since mid-2000s as data takes time for collection, adjustments and make it publically as projects takes time to be built, operate and produce. Shale gas and production data are collected from US Energy Information Administration (EIA) from 2007 to 2012 on its online website. As for GCC petrochemical production data, it is collected from Gulf Petrochemicals and Chemicals Association (GPCA) in its 2012 report about GCC Petrochemicals & Chemicals Industry Facts and Figures. The shale gas revolution started almost in 2007, which means that the study is going to focus on the period when shale gas started to boom to be marked significantly in the petrochemical industry.

   b. **Variables description**

   The data set includes one response, which is "GCC Petrochemicals production in million tons" and an explanatory one, which is "withdrawals from shale Gas wells in billion cubic feet".

   c. **Research Design**

   The study uses a regression model to statically test the existence of a relation between the dependent and independent variables and in case of existence what is its type. The method is useful for many reasons, especially that it determine the degree of the correlation between variables and its future scenarios. The initial model was:

   \[ \text{GCC} = \beta_0 + \beta_1 \times \text{Shale Gas} + e \]

   Where GCC indicates for GCC petrochemicals production in million tons, shale gas indicates to withdrawals from shale gas wells in billion cubic feet, e is the random error. After estimating the regression model, the final model will be as follows

   \[ \text{GCC} = 34.594 + 0.004 \times \text{Shale Gas} \]
d. results

The overall results, using linear regression model, indicated that there is a positive linear relation between the GCC Petrochemicals production in million tons and the withdrawals from shale Gas wells in billion cubic feet. However, that doesn't necessarily mean that they affect each other, as the model clarifies that the production of one billion cubic feet of shale gas increases the production of petrochemicals by four thousand tons only.

As shown in table 3, the mean average production of shale gas in the United States is about 4627 billion cubic feet annually. It reached its lowest value in 2007 with a total of 1990 billion cubic feet, while the highest value was a total of 8501 billion cubic feet in 2011. On the other hand, the mean average of production of petrochemicals in GCC countries was around 54 million tons annually. The production of petrochemicals in GCC countries took an upward trend starting from 2007 to 2011, started in 2007 at 43 million tons, then reached 68 million tons in 2011, excluding captive consumption.

<table>
<thead>
<tr>
<th>Table 3: Descriptive Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>GCC Petrochemicals production (excluding captive consumption), million tons</td>
</tr>
<tr>
<td>Withdrawals from shale Gas wells (billion cubic feet)</td>
</tr>
<tr>
<td>Valid N (list-wise)</td>
</tr>
<tr>
<td>Source: Author calculations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4: Model Summery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>a. Predictors: (Constant), Withdrawals from shale Gas wells (billion cubic feet)</td>
</tr>
<tr>
<td>Source: Author calculations</td>
</tr>
</tbody>
</table>
Table 5: ANOVA

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>473.305</td>
<td>1</td>
<td>473.305</td>
<td>49.483</td>
<td>.006b</td>
</tr>
<tr>
<td>Residual</td>
<td>28.695</td>
<td>3</td>
<td>9.565</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>502.000</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: GCC Petrochemicals production (excluding captive consumption), million tons
b. Predictors: (Constant), Withdrawals from shale Gas wells (billion cubic feet)
Source: Author calculations

Table 6: Coefficients

<table>
<thead>
<tr>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>.004</td>
<td>.001</td>
<td>.971</td>
<td>7.034</td>
</tr>
</tbody>
</table>

Source: Author calculations

As shown in Table 6, testing hypothesis of shale gas production parameter shows that it is highly significant, which approves the resulted relation and shows it is not a matter of coincidence. Results in table 7 indicate that there is a strong correlation between US shale gas production and GCC petrochemicals production. The degree of correlation is almost 97%, but that does not mean necessarily that they affect each other.

Table 7: Correlation between Variables

<table>
<thead>
<tr>
<th>GCC Petrochemicals production (excluding captive consumption), million tons</th>
<th>Withdrawals from shale Gas wells (billion cubic feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>5</td>
</tr>
</tbody>
</table>

Withdrawals from shale Gas wells (billion cubic feet) | Pearson Correlation | .971** | 1 |
| Sig. (2-tailed) | | .006 |
| N | 5 | 5 |

**. Correlation is significant at the 0.01 level (2-tailed).
Source: Author calculations
6. Conclusion

As illustrated in the model, results indicated that despite the existence of a positive correlation between our two variables the US shale gas production and the GCC petrochemical production, this correlation is still not strong, as the production of one billion cubic feet of US shale gas increases the production of GCC petrochemicals by four thousand tons only. This means that US shale gas revolution still is a local phenomenon and not having an impact on world energy markets in the matter of global gas prices, or feedstocks prices worldwide. The conclusion proves that the study hypothesis is not right, as the increase in U.S. shale gas production have a positive weak relation on the production of GCC petrochemicals. Also analysts believe it is too early to speak of a direct effect from U.S. shale gas on GCC petrochemical production.
The limited effect for US shale gas on global energy and manufacturing market can be the result of many reasons; the most important of them is its environmental challenges. The production of shale gas represents some environmental challenges that obstacles its production on a large scale, first challenge is the water. Fracturing of one siLNGe shale gas well would need 10,000 to 20,000 cubic meter of water. The fracturing process takes around three weeks, which means that extracting shale gas would need substantial water resources. Moreover, in the early years of the extraction process, only 20% to 80% of the injected water flows back to surface. After it flows back, 90% of that water can be recycled to be used again, the remains may contain naturally occurring radioactive materials and heavy metals that pose a risk of contamination if not treated or disposed properly.

Transportation also is a key challenge for shale gas production; as the amount of ethane that can be transported in the LNG stream for fractionation or to be transited by truck or rail is typically about 15%. It is also worth mentioning that pipeline transit has a separate set of issues as keeping ethane in the natural gas stream increases the energy content beyond the pipelines specifications. From another side, shale gas wells are normally drilled in clusters, not separated from each other. Clusters usually contain from 10 to 15 well which are drilled from a siLNGe pad. In those clusters, anything up the surface of earth is removed (35 meters high) and remains the wellhead only, which might result in removing many natural landscapes. In the same manner, shell gas wells might result in harming the surrounding aquifers and resulting in polluting water. However, recent technologies make sure of cementing the wells in the annular space to protect aquifers (see figure 1).

The effect of shale gas production is not shortened on water only, but it has its side effects on air too. Recent studies have showed that some wellheads are losing an amount worth of 9% of their total output in methane leakage. Methane itself has almost 72 times the global warming potential of carbon dioxide over 20 years. Environmental Protection Agency (EPA) report has showed that oil and natural gas, including fracking, represent the second largest source of greenhouse gas emissions.

GCC's Gas shortages can be considered as the biggest challenge for GCC petrochemical industries. The researcher used the linear regression model to figure out the relationship between GCC LNG production and petrochemical production. The equation between the three variables is like following:
GCC_i = β0 + β1* Shale Gasi + β2* GCC LNG_i + ε_i

Where:
GCC_i: GCC Petrochemicals production in million tons
Shale Gasi: withdrawals from shale Gas wells in billion cubic feet
GCC LNG_i: GCC natural gas liquidities in thousand barrels per day
ε_i: Random error

By diagnosing the previous model, it turns out that this model suffers from a multicollinearity diagnostic between the GCC natural gas liquidities and withdrawals from shale Gas wells in USA, and hence, another model was built to identify the individual effect of the GCC natural gas liquidities on the GCC Petrochemicals production.

GCC_i = b0 + b1* GCC LNG_i + ε_i

Where:
GCC_i: GCC Petrochemicals production in million tons
GCC LNG_i: GCC natural gas liquidities in thousand barrels per day
ε_i: Random error

Using the least squares method to estimate parameters, the model takes the following shape:

GCC_i = -96.715 + 0.0726* GCC LNG_i

The model indicates to the existence of a positive relationship between the production of LNGs in GCC countries and the GCC petrochemical production. According to model, every thousand barrels produced from LNGs, leads to the increase of GCC petrochemical production by seven thousand tons. As shown in table 8.
Table 8. Correlations

<table>
<thead>
<tr>
<th>GCC Petrochemicals production (excluding captive consumption), million tons</th>
<th>Pearson Correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
<th>GCC natural gas liquidities in thousand barrels per day</th>
<th>Pearson Correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCC Petrochemicals production (excluding captive consumption), million tons</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.845**</td>
<td>Sig. (2-tailed)</td>
<td>.071</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>GCC natural gas liquidities in thousand barrels per day</td>
<td>Pearson Correlation</td>
<td>.845**</td>
<td>1</td>
<td>Sig. (2-tailed)</td>
<td>.071</td>
<td>N</td>
<td>5</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

While the relation is between the two variables is so highly significant, the decrease in GCC's LNGs is expected to lead to a decrease in GCC's petrochemical production, which is likely to happen in the near future according to Booz & co.. As after decades of exporting LNG, in August 2009 the trend converted as the GCC started importing gas when Kuwait received its first LNG cargo from Russia at its fast-track LNG. The six member countries of the GCC collectively hold roughly 23% of global gas reserves. However, gas supply–demand imbalance in the region has forced the countries of the GCC, with the exception of Qatar, to consider importing gas to meet rapidly rising demand.

Figure 19: Forecasted Gas Shortage in the GCC (in billion cubic meters)

Source: Statistical Review of World Energy, 2011
There are many reasons standing behind those gas shortages, the main one is that natural gas continues to be the most consumed source of power generation in GCC. As shown in figure 20, 57% of power generation in GCC comes from natural gas and it is predicted to reach 66% in 2025 and 67% in 2030. From another point, natural gas is needed in re-injecting depleted oil fields to maintain reservoir pressure and oil production capacity. For example, the use of natural gas in depleted oil fields re-injection is expected to increase from 18 billion cubic meters in 2008 to approximately 45 billion cubic meters in 2020.

**Figure 20: power generation by source in GCC**

![Bar graph showing power generation by source in GCC](image)

Source: EIA, 2013

From another point, most of GCC natural gas production is tied to OPEC oil production quotes, which waned with global economic recession, which presents a new challenge for managing the gas supply and demand balance. In addition, the long-term gas export commitments that GCC have limits their local supply and represent a key challenge. GCC petrochemical growth cannot be taken for granted. Nevertheless excellent educational facilities, there remains a chronic shortage of professional technologists to work in the many product development centers and scientific institutions that serve the petrochemical sector which is one of the challenges facing the industry in GCC region.
References: